PANGUITCH LAKE

DRAFT Total Maximum Daily Load and Water Quality Management Plan

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TMDL Section

Waterbody ID	Panguitch Lake
Location	Garfield County; South-Central Utah
Pollutants of Concern	Total Phosphorus
Impaired Beneficial Uses	Class 3A: Cold water fishery
Loading Assessment **Current Loading** **Loading Capacity** **Margin of Safety**	 2822 kg/year 1196 kg/year 141 kg/year
Wasteload Allocation **Load Allocation** **Load Reduction**	None 2822 kg/yr (664 kg/yr-Tributaries, 2158 kg/yr-Internal) 1767 kg/year
Defined Targets/Endpoints	Lake concentration < 0.025 mg/l total phosphorus. Shift from blue-green algae dominance. Load reduction of 1767 kg/yr. Shift from eutrophic to mesotrophic conditions (Carlson TSI < 50)
Implementation Strategy	1) Lake treatment for phosphorus control. 2) Restrict grazing in lake bed and stream channels. 3) Inspect and maintain on-site systems. 4) Streambank restoration.

This document is identified as a TMDL for the Upper Sevier River and is officially submitted under §303d of the CWA for EPA approval.

I. INTRODUCTION

Waterbody Description

Panguitch Lake is located in the westernmost region of Garfield County with part of its watershed extending into Iron County. Originally, Panguitch Lake had an area of 777 acres until 1885 when the first dam was constructed on the outlet at the head of Panguitch Creek. When full the lake is about 57 feet deep with approximately 35 feet being in the natural lake and 22 feet being contained by the dam. When the reservoir is full, the 22 foot dam stores 23,730 acre feet of water for 9,400 acres irrigated under the laterals of the West Panguitch Irrigation Company.

The Panguitch Lake watershed lies in the center of the Markagunt Plateau which is in the southwestern corner of the High Plateaus subprovince of the Colorado Plateau Physiographic Province. The plateau is a large uplifted block approximately 50 miles long from north to south and from 10 to 30 miles wide from east to west. It is bordered by the Hurricane Fault Zone on the west, the Sevier Fault Zone on the east,. The Pink Cliffs on the south, and the Dog Valley highline on the north. Elevations in the Panguitch Lake watershed range from over 11,000 feet in the upper Castle Creek drainage to 8,200 feet at the lake. In places (such as the Panguitch Lake watershed) the plateau has been eroded into deep steam channels, semi-rounded ridges and knolls and does not have the appearance of a plateau.

Sedimentary rocks underlying the plateau are believed to range in age from Cambrian to Tertiary . The Tertiary Claron or Wasatch Formation is exposed around the south and west edges of the Markagunt plateau. Consolidated rocks exposed in the Panguitch Lake watershed are either extrusive igneous rocks of the Tertiary Brian Head Group which make up approximately 96 percent of the watershed, or Quaternary (probably recent) basaltic lava flows which make up about 4 percent of the watershed at its southeastern corner.

Land use in the Panguitch Lake drainage is largely range and forest in nature and falls into three categories.

1. Forest – Range: 92 % of the drainage basin is multi-use forest and range. Both public and private lands are included in this category.
2. Water: 5% of the drainage area is covered by water. This includes Panguitch Lake, Horse Lake , and the streams in the basin.
3. Residential: 3% of the drainage is used for low density dwellings. The Upper Sevier River Watershed Management Plan identifies 750 developed lots in the Panguitch Lake watershed utilizing septic systems for waste disposal. At the time of the Phase I Clean Lakes Study there were approximately 300 developed sites. There are no communities in the basin.

Surface and Groundwater hydrology

There are no known groundwater studies of Panguitch Lake or its watershed. The lake basin is probably resting on either limestones or extrusives of the Claron Formation or possibly a basal unit of Brian Head Group, all of which have been demonstrated to produce flowing wells and large springs on the Markagunt Plateau (Gregory, 1949; Doelling, 1975). Limestones underlie much of the area and the Karst (sinkhole) topography in some areas points to the possibility of solution channels and groundwater movement through limestone solution channels. The amount of infiltration into and exfiltration of water from the lake basin is not known.

Springs supply a large percentage of the water in the tributaries to Panguitch Lake. Springs supply virtually all of the water to Blue Spring Creek except for snowmelt runoff. They also supply significant amounts to Castle, Bunker, Clear and Skoots Creeks. Virtually all of the Ipson Creek water after snowmelt runoff is over originates from springs in the upper part of the canyon immediately below Horse Lake.

The Markagunt Plateau contains the headwaters of the Sevier River and contributes more to the rivers flow than does any other single plateau of the High Plateaus. Most of the streamflow in the high elevation streams of the watershed occurs during spring runoff from snowmelt. The major tributaries to Panguitch Lake include Blue Spring Creek, Clear Creek, and Ipson Creeks which contribute 12,560, 2731, 1557, and 1257 acre feet per year of the surface flow, respectively. A transbasin diversion from Castle Creek outside the basin provides a majority of the flow to Deer Creek (a tributary to Blue Spring Creek) thus the high proportion of the streamflow attributed to that watershed.

Statement of Intent

This TMDL addresses the water quality impairment of Panguitch Lake for submittal to the United States Environmental Protection Agency. The goal of the TMDL is to meet water quality standards associated with the waterbody's designated beneficial uses.

II. Water Quality Standards

This document addresses water quality impairments for Panguitch Lake through the establishment of Total Maximum Daily Loads (TMDL) for pollutants and sources of concern. Panguitch Lake been listed on the 2002 303(d) list of impaired waters (see Map 1). The State of Utah has designated Panguitch Lake as coldwater (3A) fisheries and impairment of this designated uses exist due to excessive phosphorus and low dissolved oxygen.

Impaired Waters
Utah's Year 2002 303(d) list identifies Panguitch Lake as being impaired due to water quality numeric exceedences of the maximum total phosphorus criterion and the minimum dissolved oxygen criterion for the support of a coldwater fishery (see Table 1).

Table 1. Impaired Waterbodies and pollutants of concern.

Waterbody	Waterbody ID	Impaired Designated Use	Cause of Impairment
Panguitch Lake	**UT16030001-005**	**3A**	**Total Phosphorus** **Low Dissolved Oxygen**

The beneficial uses, as designated by the State of Utah (DWQ, 2000b), for Panguitch Lake are:

- 3A - Protected for cold water species of game fish and other coldwater aquatic life, including the necessary aquatic organisms in their food chain.
- 2B – Protected for secondary contact recreation such as boating, wading, or similar uses;
- 3C – Protected for nongame fish and other aquatic life, including the necessary aquatic organisms in their food chain;
- 3D – Protected for waterfowl, shore birds and other water-oriented wildlife not included in Classes 3A, 3B, or 3C, including the necessary aquatic organisms in their food chain
- 4 – Protected for agricultural uses including irrigation of crops and stock watering

II. Water Quality Standards and Impairments

Utah water quality standards (Utah WQS) (State of Utah, 2000, UAC R317-2) and the 303(d) listing criteria (UDEQ - DWQ, 2002) provide the criteria to make an initial assessment of water quality conditions. The Utah water quality standards establish a narrative criteria for coldwater fishery (Class 3A) waters (Table 6.). While additional designated uses exist for Panguitch Lake, 3A classification carries the strictest criteria for the pollutants of concern (POCs).

Table 2. Utah Water Quality Criteria for Class 3A Waters

Parameter	Criterion Concentration
Total Phosphorus -Lakes	0.025 mg/l
Dissolved Oxygen -Lakes	4.0 mg/l (minimum) >50% of water column

DWQ lists any waterbody assessed as ‘partially supporting’ or ‘not supporting’ its beneficial uses on the 303(d) list with the exception of those waterbodies for which a TMDL study has already been completed and approved by the EPA. According to DWQ's assessment of the Upper Sevier River segments of the river are not meeting beneficial uses associated with coldwater fishery (3A) . The 303(d) listing criteria provide guidance on evaluating beneficial use support status based on the number of violations of the water quality criterion as listed in Table 3.

Table 3. 303 (d) Criteria for Assessing Beneficial Use Support

Degree of Use Support	Dissolved Oxygen	Total Phosphorus
Full Support (3A Lakes)	Any lake profile at the deepest site with >50% of water column above the 4.0 mg/l DO criterion.	Less than 10% of samples exceed 0.025 mg/l total phosphorus criterion
Partial Support (3A Lakes)	Any lake profile at the deepest site with between 25 - 50% of water column above the 4.0 mg/l DO criterion.	Between 10% and 25% of samples exceed 0.025 mg/l total phosphorus criterion
Non-Support (3A Lakes)	Any lake profile at the deepest site with <25% of water column above the 4.0 mg/l DO criterion.	Greater than 25% of samples exceed 0.025 mg/l total phosphorus criterion

According to the period of record for the deepest site on Panguitch Lake (594948) approximately 86% of the depth integrated samples gathered from 1980 to the present exceed the state criterion for total phosphorus of 0.025 mg/l.

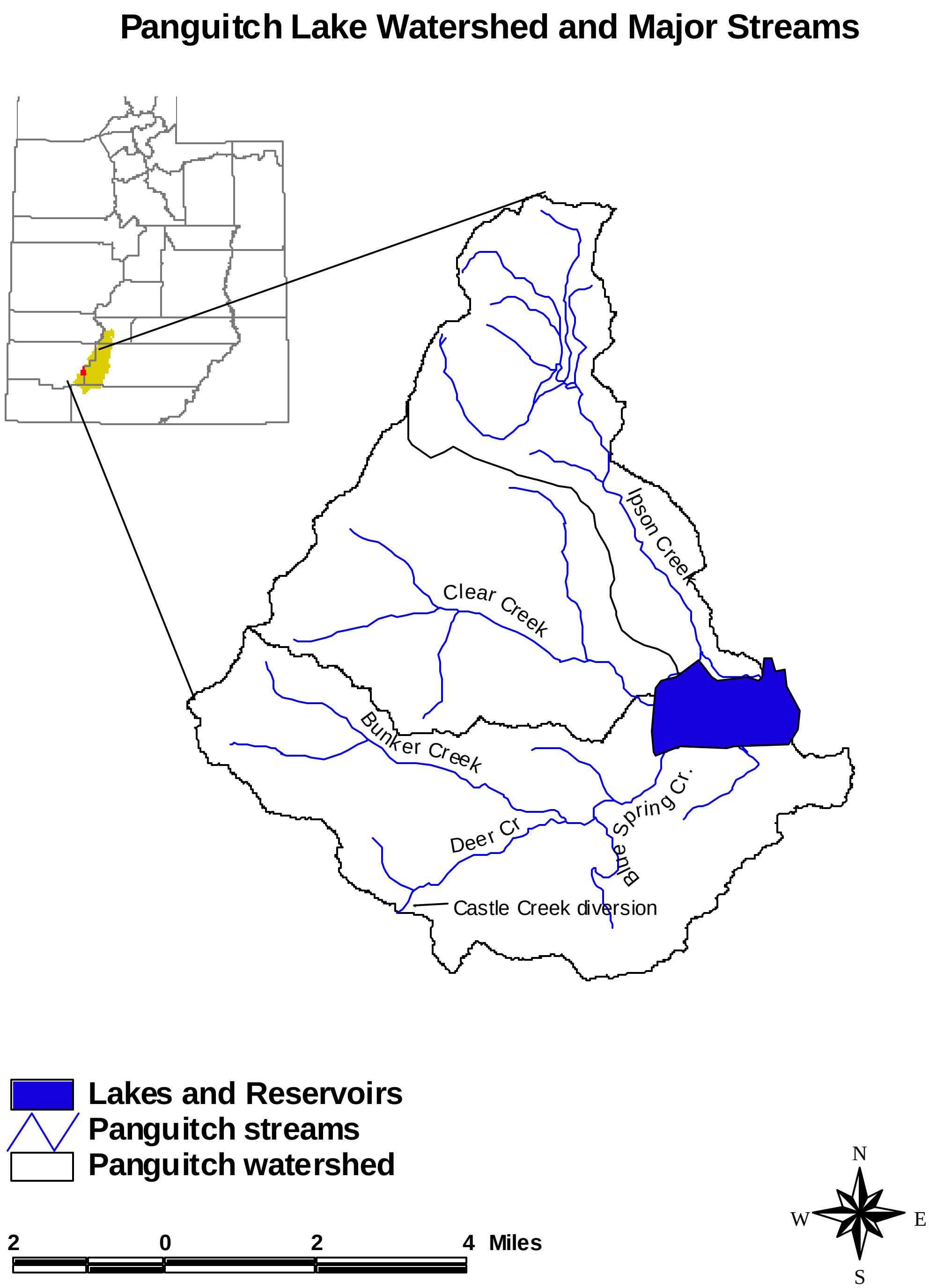
Similarly, dissolved oxygen minimum values are not being met for Panguitch Lake to support a coldwater fishery. In the years from 1997 to 2003, 27% to 56% of the water column was below the 4.0 mg/l criterion (mean of 41%).

Diatom flora in Panguitch Lake was identified as part of the Clean Lakes Study and was found to be highly productive and diverse. The dominance of diatom species such as *Stephanoiscus minutula* and the dominance of Cyanophyta such as *Aphanizomenon* and *Anabaena* is particularly indicative of eutrophic conditions.

III. Pollution Assessment

Nonpoint Sources

The Clean Lakes Study delineated and described nonpoint sources and loading from subbasins of the Panguitch Creek watershed (see map 1.)



Ipson Creek

The Ipson Creek subbasin is the smallest of the three tributaries to Panguitch Lake. It encompasses 3,047 hectares (7,530 acres) and occupies the northwestern part of the basin and includes Horse Valley. It covers 25 percent of the basin's total area but supplies only 10 percent of the inflow. Slopes are steep in the lower 6 miles of the stream channel which is narrow with nearly vertical cliffs. Summer home development is occurring on the slopes in the lower half mile of the canyon. Wastes are disposed of in septic tanks and pit privies. Cattle are grazed in the lower 6 miles of the sub-drainage and sheep are grazed in Horse Valley. A light duty road from the north shore road runs 10 miles along the east side of the subbasin to and through Horse Valley. Vegetation in the subbasin includes fir-spruce-aspen at higher elevations on north facing slopes. At lower elevations ponderosa pine, juniper, pinyon pine, sagebrush, forbs, shrubs, and grasses are dominant. Horse Valley is covered with grasses, sagebrush, and forbs. Riparian vegetation is good in the lower 6 miles of the subbasin.

Clear Creek.

Clear Creek is primarily used for recreation, grazing and summer home development. It comprises approximately 29% of the area of the watershed but only 19% of the flow to the lake. Water from Clear Creek is used for irrigation on meadows west of the lake and flow usually only reaches the lake as spring runoff from snowmelt. Vegetation in the basin is primarily spruce-fir-aspen with ponderosa on south facing slopes. Understory of shrubs grasses and forbs is good to excellent as are riparian areas in the watershed.

Deer Creek

Due to a trans-basin diversion Deer Creek also contains some of the watershed of Castle Creek. The ditch connecting the watersheds has eroded a deep channel in the steep slope between the watersheds. As a result riparian vegetation is absent and erosion is severe due to high flows. The effects of the extra discharge from the ditch can also be observed in streambank erosion along Deer Creek. The subbasin, which contains 7 percent of the total land area in the basin, produces a disproportionate 29 percent of the total tributary inflow due to the trans-basin diversion.

Bunker Creek

The Bunker Creek subbasin includes the Bunker Creek drainage above its confluence with Deer Creek. About 5 miles of unimproved roads and four-wheel-drive trails exist in the subbasin. Cattle graze throughout the subbasin which is covered by a spruce-fir-aspen forest with associated grasses forbs and shrubs. The lower quarter mile of stream crosses a grass meadow at the west end of Blue Spring Valley. Riparian vegetation is good to excellent except in the meadow where it is poor. Lower Bunker Creek and Deer Creek below their confluence include the meadow area west of Blue Spring Creek's confluence with Bunker Creek. Its stream bank are unstable with very little riparian vegetation. The meadow soils are composed of easily eroded lake bottom sediments that are easily sloughed off into the streams. Vegetation is of meadow grasses and forbs. Runoff also comes from a small area of hillside with ponderosa pine and sagebrush. Cattle are grazed each summer on the Blue Spring Valley meadow which is under private ownership.

Blue Spring Creek

The Blue Spring Creek subbasin includes the southern part of Blue Spring Valley and the surrounding hillsides as well as the high altitude drainages of Bunker, Deer, and Castle Creeks. This is the largest in the study area, encompassing 4,287 hectares (10,595 acres). It occupies only 35 percent of the basin's land area, yet supplies 75 percent of the stream inflow to Panguitch Lake. The source of water is primarily Blue Spring which exhibits uniform flow helps resulting in more stable streambanks than Bunker Creek's throughout Blue Spring Valley. The hillsides above the meadow are spruce-fir-aspen forests with some ponderosa pine at lower elevations. Riparian vegetation is good but consists primarily of grasses. Some summer homes are located in the south end of Blue Spring Valley. Water from Blue Spring Creek irrigates the meadows at the southwest corner of the lake. The USFS Panguitch Lake Campground and Guard Station are in the lowest part of the subbasin. Some summer homes are also in the subbasin immediately above the lake. Riparian vegetation below Blue Spring Valley is good. Vegetation is spruce-fir-aspen on north facing slopes and ponderosa pine on south facing slopes.

The Clean Lakes Study identified that a majority of phosphorus loading to Panguitch Lake originated from Blue Springs Creek. Examination of the Blue Springs Creek watershed indicates that the source of most of the phosphorus is naturally-occurring, phosphorus-laden soils in the upper watershed related to erosion. Riparian vegetation is of high quality in some reaches while in other areas it was identified as poor to nonexistent. The lower section of Blue Springs Creek on the National Forest is of high quality as is the Bunker Creek section on the forest above the Blue Springs meadow. The Clean Lakes Study identified areas of Blue Springs Creek, Bunker Creek, and Deer Creek from the confluence of Bunker Creek on the private property including the forest up to the transbasin diversion from Castle Valley is of poor to nonexistent riparian quality. This poor condition was due to overgrazing on the private and forest sections. Large volumes of water diverted from Castle Valley caused excessive erosion in those reaches.

Since the original Clean Lakes Study a number of successful restoration projects have been implemented in the area near the confluence of Deer and Bunker Creeks and on Blue Springs Creek (See Photo 1).

The Clean Lakes phase II Study (1989) estimated that below restoration projects TSS concentrations were reduced from 71 mg/l to 3 mg/l and total phosphorus loads were reduced by 73 kg/year. Recent data (see loading analysis below) indicate that the contribution of total phosphorus from Blue Springs Creek has been reduced by 124 kg/year.

Photo 1. Blue Springs Creek before and after restoration.

According to the Clean Lakes Study, soil sample analysis indicates that many soils on the upper watershed are extremely high in phosphates. Phosphorus levels in Panguitch Lake can be directly attributed to the transport of upper watershed soils through erosion during spring runoff. The additional phosphorus supplied to the lake results in a accelerated rate of eutrophication. Late summer and winter algae blooms with dense macrophyte (weed) growth causes adverse water quality conditions. Spring snow melts contribute large flows responsible for most erosion. But as was previously mentioned, good riparian vegetation on stream sections such as upper Bunker Creek, effectively hold the soils and prevent most erosion. The large and excess stream flows diverted into the Blue Springs system were contributing substantially to the high phosphorus in Panguitch Lake by eroding away large section of stream banks prior to restoration.

Other minor streams includes the other nine subbasins, some very small intermittent stream drainages, the lake, and its surrounding shoreline drainage area. Land unaccounted for in the previous subbasin descriptions has some grazing and is highly used for recreational purposes. Vegetation in the shoreline drainage area is primarily sagebrush, pine, and juniper with a poor cover of associated grasses, forbs, and shrubs.

Nonpoint sources of total phosphorus originate primarily from sediment from streambank erosion, summer home development, and cattle grazing. While cattle grazing has decreased since over the years summer home development has increased significantly from ~300 at the time of the Phase I Clean Lakes Study to over 750 developed lots today. This increase of septic systems and recreation likely offset some of the nutrient reductions achieved through restoration activities such as installation of fish cleaning stations, streambank restoration in the Blue Spring Creek watershed, and public education.

Point Sources

Currently, no point sources exist within the Panguitch Lake watershed.

IV. Linkage Analysis

A major problem experienced in Panguitch Lake is oxygen depletion in the water column. This problem stems largely from decomposition of macrophytes and phytoplankton which represent a considerable biological oxygen demand in the hypolimnion where they settle. When stratified the hypolimnion has the potential to become anoxic through much of the profile. Historic fish kills have also occurred due to the lack of oxygen in the water column.

Lake Status

The Carlson Trophic Status Index is often used to classify or predict the productivity of a lake compared to typical lakes and is determined by three indicators, chlorophyll a, secchi depth and total phosphorus concentrations. The latter two are typically used as surrogates for the most important indicator of lake productivity which is chlorophyll a. Historically, TSI values for Panguitch Lake have demonstrated that it is primarily an eutrophic to mesotrophic system with high levels of primary productivity (measured as chlorophyll a). While TSI values have dipped below 40 (the threshold between meso-and oligotrophy) in 2000 - 2003, there is no discernable trend whether the system is improving or degrading based on TSI values (Fig. 1a). Secchi depth and TP TSI values were plotted for comparison (Fig1b.). While no trends in these alternate measures of trophic status are apparent, there appears to be less variation in their values, particularly in recent years in which chlorophyll a TSI varies widely. Additional monitoring will be helpful to determine whether there is a downward trend in TSI values and improved trophic status.

Figure 1a. Chlorophyll a TSI by year for Panguitch Lake Above Dam.

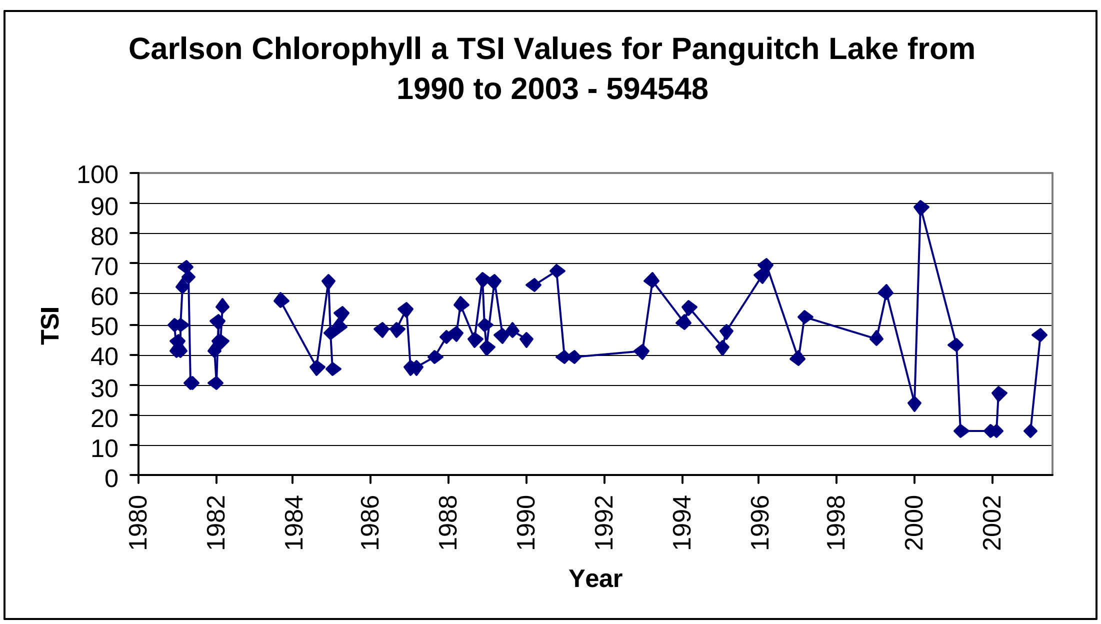
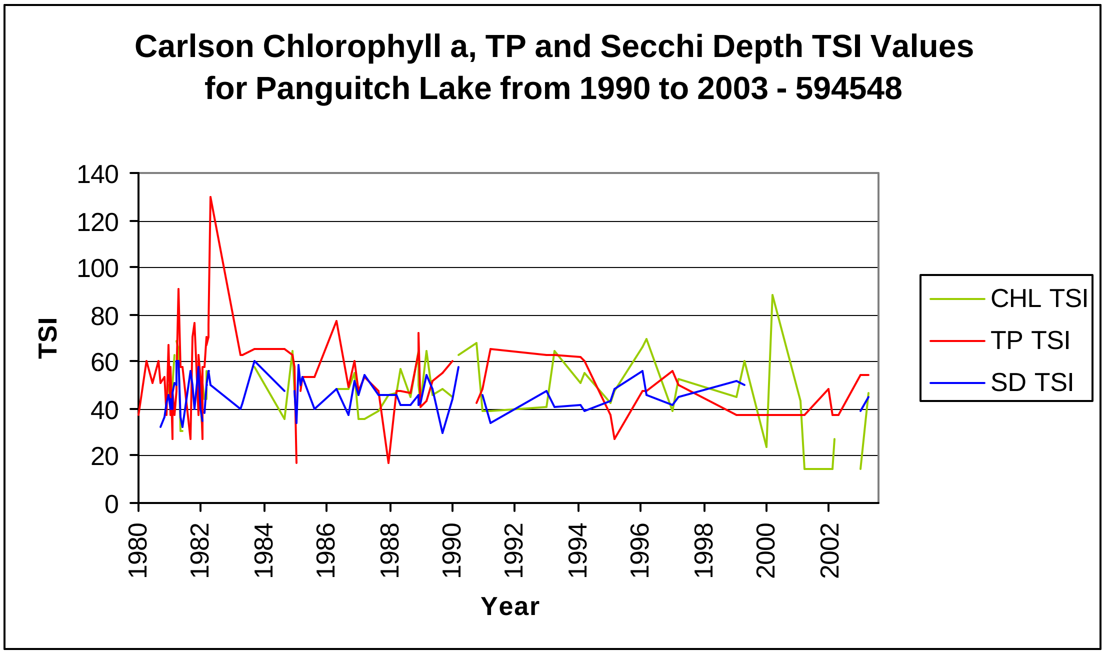
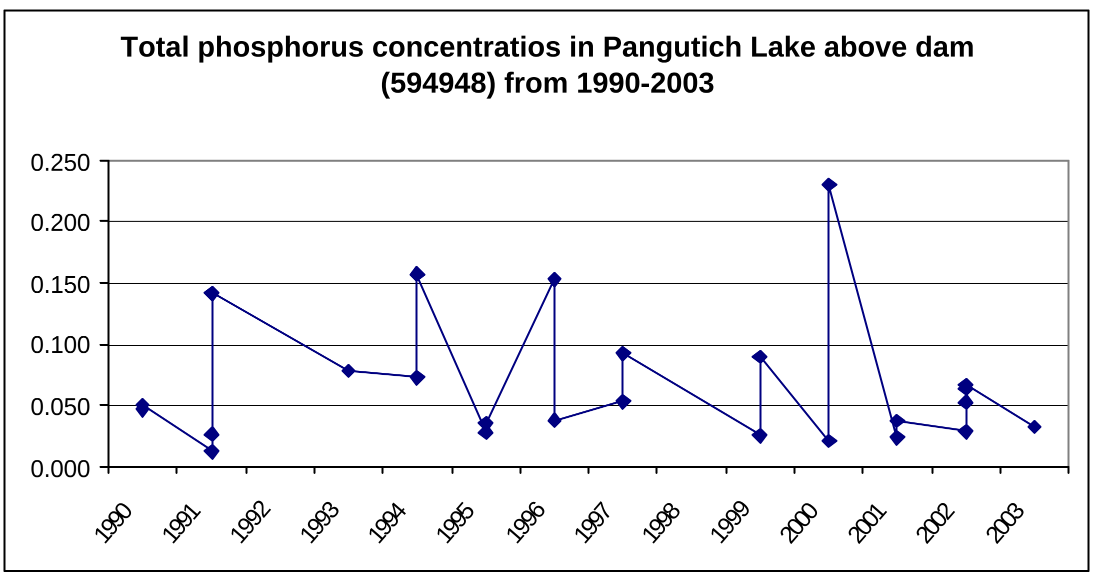


Fig 1b. Secchi depth (SD), total phosphorus (TP) and Chlorophyll a (CHL) TSI Values.



Similarly, in lake concentrations of phosphorus (Figure 2) do not appear to indicate a definite trend. Depth integrated TP concentrations for the period from 1990-2002 at the deep site above the dam (594948) record fluctuate widely, ranging from 0.012 mg/l to 0.230 mg/l. Mean concentration for the dataset was 0.066 mg/l. Similarly, average depth integrated total phosphorus for both lake sampling sites averages approximately 0.066 mg/l.

Figure 2. Average total phosphorus concentrations in Panguitch Lake.



Biological conditions

Algae – The Clean Lakes Study (1983) found that phytoplankton types and numbers indicated Panguitch Lake was an eutrophic system. Algal indicators of this eutrophy, Anabaena, Aphanizomenon and Microcystis are abundant in the lake in late summer and fall. According to the Clean Lakes Study, considerable variation in species and numbers was observed at different times but indications were strong that the lake was eutrophic. Similarly, phytoplankton data from samples collected in 2000 and 2002 suggest that Panguitch Lake is still dominated by Cyanophyta species, and exhibit low bulk densities of Chlorophyta species. Aphanizomenon and Microcystis are still the dominant phytoplankton found in the lake.

Macrophytes – Five species of rooted aquatic macrophytes were found in Panguitch Lake during the study, small beds of Polygonum coccineum and Ranunculus aquatilis occurred in shallow areas on the north, east and southeast shores of the lake with extensive beds of the two species occupying the shallow western shoreline of the lake. In places the two species occur up to 600 feet from the shoreline. Two species of Potamogeton, P. filiformis and P. Pectinatus occurred throughout the macrophyte beds with P. coccineum and R. aquatilis and extended 100 to 200 feet farther out into deeper water beyond the Polygonum and Ranunculus beds. Myriophyllum spicatum was found in the boat dock areas and along steeper shorelines as well as the deep water border of the macrophyte beds. There was not a great difference between areas of macrophyte coverage in 1981 and 1982. Fluctuating water levels along the shorelines of reservoirs helps to explain the lower species diversity in reservoirs when comparing them to natural lakes. Panguitch Lake can have a 3 to 8 feet fluctuation in water level annually. As the water drops, the Polygonum and Renunculus areas are replaced by grasses in the newly exposed shore areas.

V. Water Quality Analysis

For the Clean Lakes Study, water quality was determined largely from data collected on a number of stream locations in the watershed over an 18 month period beginning in April 1981. Recent data collection has occurred solely at the mouths of three tributaries, Blue Springs, Ipson, and Clear Creeks and are presented below, following a discussion of the Clean Lakes Study findings. Complete water quality analysis and tables are contained in the Phase I Clean Lakes Study (1983), however a basic review of the water quality data indicates that the waters were of generally good quality. Based on weighted averages there are low TDS values, ranging from about 80 mg/l to 130 mg/l; low alkalinity ranging from about 45 mg/l to 115 mg/l. TSS values are occasionally quite high, especially during spring runoff or heavy summer rainstorms. Total phosphorus concentrations are moderately high ranging from 0.003 mg/l to 1.585 mg/l. Nitrogen species are low with TKN below 0.3 mg/l, NH_3 below 0.10 mg/l, and NO_3 below 0.2 mg/l.

The highest sediment, nitrogen and phosphorus generation rates were found in the southwestern area of the basin. The highest occur in the lower Bunker Creek subbasin which had a serious soil and bank erosion problem as it transverses a rich meadow near its confluence with Blue Spring Creek. The Deer Creek and upper Blue Springs Creek subbasins also exhibited high sediment, nitrogen and phosphorus generation rates. Deer Creek suffers erosion in its upper reaches up to the Castle Valley ditch area and in its lower reaches near the confluence with Bunker Creek. Blue Spring Creek experienced somewhat lower but still high loading rates as it traverses the old lake bed meadow. The Clean Lakes Study found that its erosion problem is minimal compared to that in adjacent Bunker Creek. Since the Clean Lakes Study a number of successful restoration projects have been implemented to address the sediment and phosphorus sources near the confluence of Deer and Bunker Creeks (see below).

Ispon Creek and Clear Creek exhibit lower pollutant loading rates. During the 1980-1982 period, they carried low concentrations, although Clear Creek still carried a moderately high sediment load.

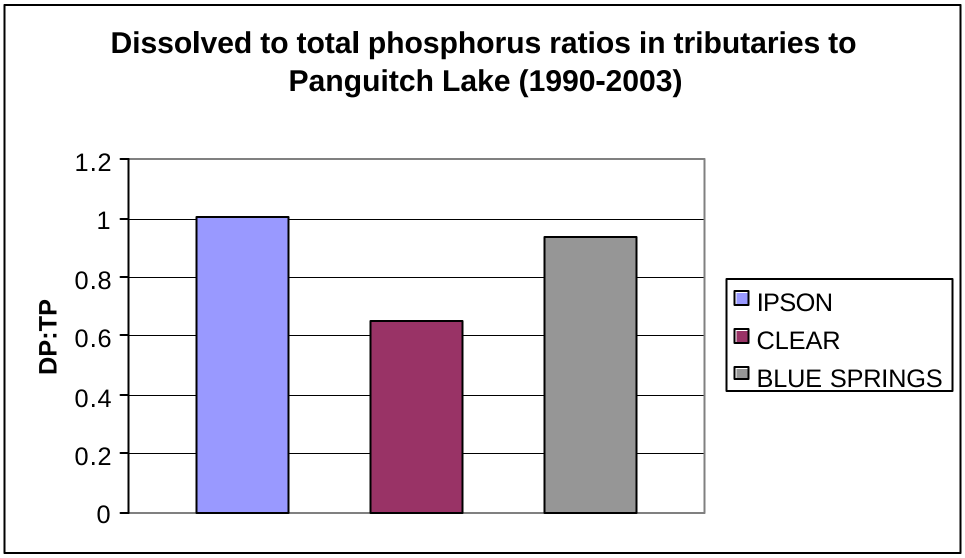
Nutrient loading for Panguitch Lake are given in Table 4. These nutrient loads were based on the average year, trend-curve nutrient concentrations and average year flow rates utilized in the Clean Lakes Study. They were based on trend-curve fitting to give a "typical" year.

Table 4. Load summaries for tributaries of Panguitch Lake (Clean Lakes Study, 1983).

Source	Flow (acft/yr)	% Total	Ortho-phosphorus (kg/yr)	Total Phosphorus (kg/yr	% Total	Natural Background %	Human Caused %	Human Caused (kg/yr)
Blue Spring Creek	12560	64.9	364	571	57.7	52%	48%	273
Clear Creek	2731	14.1	136	194	19.6	43%	37%	72
Ipson Creek	1557	8	84	100	10.1	75%	25%	25
Other Drainage	1257	6.5	62	78	7.9	50%	50%	39
Precipitation	1257	6.5	31	47	4.7	100	0	0
Total	18105	93.5	677	990	100	59%	41%	409

Mean total phosphorus in the inflow at 0.041 mg/l is a moderate, though somewhat high, value and indicates mesotrophic to mildly eutrophic loading. However, the inorganic nitrogen at 0.22 mg/l is low and suggests nitrogen limitation in the lake since the overall N/P ratio is only about 7. Orthophosphorus values were also high at 0.028 mg/l and indicates that a high fraction of the total phosphorus actually measured in the lake water is available for algal growth. Although the Clean Lakes Study suggests that total phosphorus loads can be attributed to sediment born (inorganic) phosphorus, data from that study demonstrate that the majority of the total phosphorus load is comprised of the more organically derived and bioavailable fractions of orthophosphorus. Recent data also demonstrates that the majority of the total phosphorus load is composed of bioavailable dissolved phosphorus (Fig. 3).

Fig. 3. Ratios of dissolved to total phosphorus in tributaries to Panguitch Lake.



Recent data were also used to estimate annual loading information and mean inflow concentrations (see Table 5.).

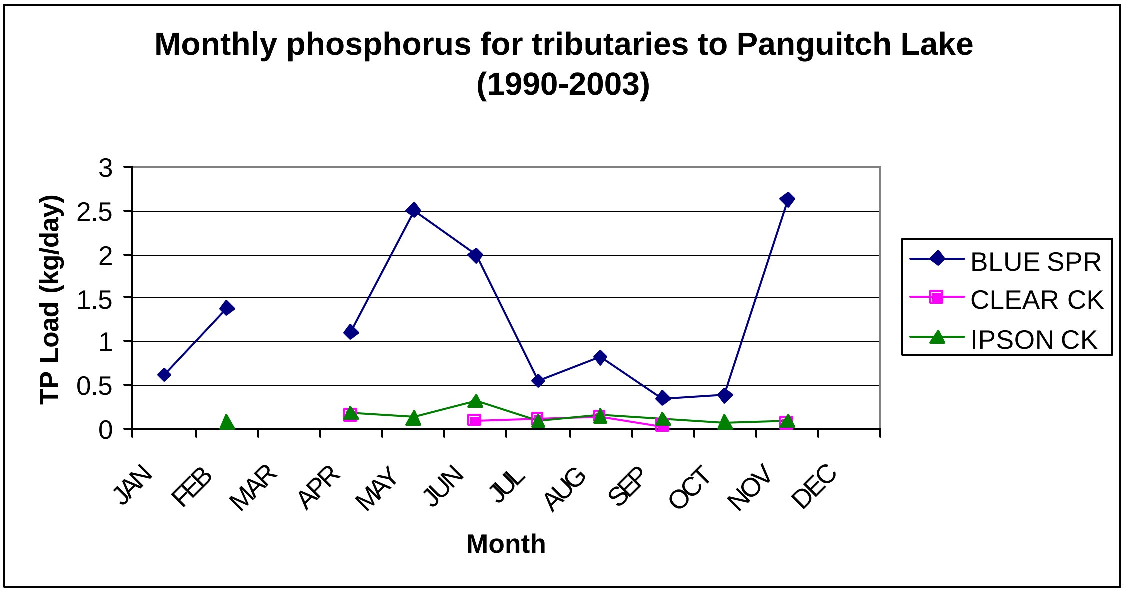
Table 5. Mean inflow phosphorus concentration and loading (1990-2003)

Tributary	Mean TP (mg/l)	Annual Load (kg/yr)	Mean Flow (cfs)	% Total
Blue Springs Cr.	0.045	447.6	11.1	85.1
Clear Cr.	0.048	31.4	0.7	5.9
Ipson Cr.	0.053	47.6	1.0	9
Total	-	526	-	100

Annual loads for the tributaries of Blue Springs, Clear and Ipson Creeks are 448, 31, and 48 kg/year, respectively for a total load of 526 kg/year. For this dataset, Blue Springs Creek provides 85% of the total phosphorus load to the lake compared to the 58% estimated in the Clean Lakes Study. This loading is lower than the 571 kg/year estimated in the original Clean Lakes Study. It is uncertain whether this discrepancy is a function of improved conditions in the watershed or error associated with the dataset, since there is not a complete year round dataset to estimate loading. In addition, much of the seasonal data has been collected during the last few years which have been marked by drought conditions and lower than normal stream flows.

Samples collected between 1990 and 2003 were sorted by month and yearly loads estimated for stations displayed in Figure 4. As mentioned above, several months of data are not available for some sites particularly in the early spring when peak runoff typically occurs.

Figure 4. Mean monthly total phosphorus for tributaries to Panguitch Lake (1990-2003).



Load allocations were estimated for major sources of phosphorus in the watershed. These include grazing, septics and sources of sediment. Grazing contributions were estimated from information on grazing allotments on the Dixie National Forest and on private lands. The total number of animals in each watershed varies by season as cattle are moved from summer to winter range, as well as into and out of the watershed. The numbers and loading estimates presented here are based on the numbers of animal in close proximity to a stream or the river with full access to the stream channel. Literature values for phosphorus content of manure (~0.02 kg/day/animal) were used to calculate the gross production of TP from cattle (NRCS,1999), to which an assumed delivery ratio of 10% was applied to estimate the contribution of the total load to the river (Koelsch and Shapiro, 1997). In addition, numbers for animals grazing below the high water line on the lake bed were obtained and a higher delivery rate of 50% was applied. It is assumed that when inundated by high water, these areas will provide a higher rate of phosphorus loading to the lake. The 70 cattle which spend 120 days each year on the lake bed meadows contribute an additional 9.2 kg/year total phosphorus to the lake in addition to the loading from the tributaries.

Simple methods were used to estimate the contribution of systems in these watersheds and include the following: The number of developed lots in each area were estimated as part of the Upper Sevier River Community Watershed Project. Assuming an average occupancy of 2.5 persons for 6 months of the year and applying a loading rate of 5 kg/person/year TP (Sarac et al, 2001), the phosphorus content of septic effluent was estimated. Based on best professional judgment a 20% failure rate was applied to these calculations to generate a load for the septic systems in the Blue Springs, Clear, and Ipson Creek drainages. Results of these estimations are presented in Table 5.

Table 6. Phosphorus allocations by watershed and source type.

Source	Ipson and Clear Creeks	Blue Springs Creek	Blue Springs Meadows	Total	% of Total
Sheep	22	2		25	5
Cows		18	82	100	19
Septics				117	22
Upland/streambank erosion				284	54
Total Measured Load				526	100

Internal Loading

Sediments have been likened to the "memory" of a lake or reservoir for its previous trophic state. Lakes that are oligotrophic tend to remain that way, despite increasing loadings of phosphorus from the watershed, while eutrophic lakes tend to resist efforts at restoration by making up for reductions in external phosphorus loading by calling on their accounts of sediment phosphorus stored during previous months or years. However, not all sediments "bank" their phosphorus with the same efficiency. The efficiency depends on the chemical mechanisms responsible for storing phosphorus in a particular lake sediment.

Possible storage mechanisms can be broadly categorized into four forms: exchangeable-P, iron-P, apatite-P, and organic-P. The first form is the most readily lost from the sediments, but pool sizes are often relatively small. The majority of iron-P represents a much larger pool of stored phosphorus in many lake and reservoir sediments, and the size of this pool is highly correlated with the rate of release of phosphorus from lake sediments at times when the water overlying such sediments is anaerobic. This form of P also has sediment if sediment is suspended into the water column by winds, spring runoff, or overturn of the lake water column. Apatite-P may form in calcium-rich sediments from decaying algae or iron-P, but it is often more closely associated with inputs of suspended solids eroded from the watershed. Once formed, it is permanently removed from circulation with the overlying water or algae. Organic-P consists predominantly of highly unavailable phosphorus associated with humus, although a smaller fraction may become available for circulation after a sufficient period for decomposition.

The sediment chemistry outline above suggests that the deep lake sediment could support low to moderate rates of P release under anaerobic conditions. Laboratory incubations of intact sediment cores that aerobic P release averaged 0.2 mg/m2-day over a 45 day period, while P release under anaerobic conditions increased to 14 mg/m2-day. These rates must be related to the hydrologic regime of the reservoir in order for predications to be made of the exact corresponding impact. However, they may be compared to estimate release rates of 8-12 mg/m2-day for the lower reaches of the arms of Flaming Gorge Reservoir and Deer Creek Reservoir, or 15-50 mg/m2-day for some eutrophic Canadian and European lakes. Not only are the Panguitch values relatively small, but the "equilibrium" concentration of P maintained by the sediments with the overlying water is much lower (300-350 ug/l) than that observed for other intermountain reservoir sediments.

In general, the Clean Lakes Study asserted that sediments of Panguitch Reservoir indicate that the potential for internal phosphorus loading is relatively low, provided that the reservoir is managed properly. If the central basin can be prevented from becoming anoxic, P release can be expected to be quite low, and the reservoir should return to a much lower trophic state than was observed in the early 1970s or in the early decades of this century. In addition the Study claimed that the actual trophic state would depend primarily on the rate of external P loading and if loads were reduced anaerobic conditions near the sediment water interface and thus sediment loading would be minimal.

Lake Modeling

The Vollenweider model (1976) was utilized to analyze the phosphorus loading and compare loading rates to observed in-lake phosphorus concentrations. The basic equation and model inputs for Vollenweider's phosphorus response model are summarized in Figure 5. The model is useful in relating the inputs of phosphorus to a lake to the in-lake concentration of total phosphorus. Conversely, loading rates can be estimated from the in-lake concentrations and compared to measured loads from tributaries and other sources.

Figure 5. Phosphorus Response Model

$$P = \frac{W'}{zQ + v_s}, \quad \text{where}$$

P	=	Inlake TP concentration (mg/l)
W'	=	Areal loading rate (g/m^2/yr)
z	=	Mean lake depth (m) = 6.4 m
Q	=	O/V (where O= lake outfall and V=lake volume*) = 0.66
v_s	=	$k_s z$ (net settling velocity in m/year) = 5.18 m/yr
k_s	=	$Q^{0.5}$ = 0.81

*15678 and 23730 acre-feet, respectively (DWR,2003).

Utilizing this response model and the aerial loading rate from measure tributary loads results in a predicted inlake concentration (P) of 0.014 mg/l, much lower than the observed mean concentration measured in the dataset from 1990-2003 of 0.066 mg/l. Conversely, predicted aerial loading from the observed inlake TP concentration (3636 kg/yr) was much higher than the loading estimated from stream sampling data (526 kg/yr). Internal lake sediment loading rates and literature atmospheric loading rates were applied to the total aerial loading rate in an effort to account for the higher observed lake concentrations. As Clean Lakes Study, laboratory study of sediment samples estimated that sediment loading ranges from 0.073 to 5.11 g/m^2/yr under aerobic and anaerobic conditions, respectively. Adjustments were made to the duration and lake area under anaerobic conditions utilizing lake bathymetry, lake profile data, and best professional judgment. These included the estimation that anaerobic conditions occurred on average approximately 85 days/year over only 30% of the lake area. Based on these considerations, a sediment loading rate of 0.4244 $g/m^2/yr$ was utilized for the phosphorus response model. A summary of the loading estimates is included in table 7.

Table 7. Loading estimates for Vollenweider model.

Source	**Load (kg/yr)**	**Loading rate ($g/m^2/yr$)***
Tributaries	526	0.103
Other drainage	78	.015
Precipitation	51	.01
Grazing in lake bed	92	.02
Internal sediment loading	2158	0.424
Total	2822	0.554

*Obtained by dividing load by lake area (5.09×10^6 m^2)

Model results yielded a predicted inlake concentration of 0.061 mg/l TP which comparable to the observed mean concentration of 0.066 mg/l. The sediment loading rate corresponds to 2158 kg/yr which is approximately 4 times that of tributary loading. Therefore, it is likely that with current internal loading Panguitch lake will continue to exhibit high in-lake concentrations of TP ,continued algae blooms, and resuspension of phosphorus from anaerobic sediments.

VI. TMDL Water Quality Targets and Endpoints

The primary recommended endpoints for Panguitch Lake based on water quality standards are mean inlake concentrations of total phosphorus of 0.025 mg/l, and dissolved oxygen above 4.0 mg/l in greater than 50% of the water column. Secondary endpoints should include a shift from blue-green dominated algal populations and a Carlson Trophic Status Index less than 50 (Mesotrophy). Using the phosphorus response model (Vollenweider, 1975), an in-lake concentration of 0.025 mg/l corresponds to a loading rate of 0.235 $g/m^2/yr$ or 1196 kg/year. Current loading estimates of 2822 kg/year would require a reduction of greater than 60% total phosphorus to meet this goal.

In the Clean Lakes Study, phosphorus loadings in the drainage basin were evaluated with the objective of estimating the reduction in phosphorus loading which might be possible if a rather “complete” program of Best Management Practices (BMPs) were implemented in the basin. The approach used was to compare nutrient loadings in each subbasin to those emitted from the “less-disturbed” areas in the basin. The Clean Lakes Study (Table 4) identified the final estimates for the estimated best case phosphorus reduction possible in the basin which would be about 409 kg/yr (based on 911 kg/year total tributary load). However, the study did not include internal loading into the total loading estimate for the lake.

Adopting the “best-case” scenerio described in the Study, a 50% reduction in watershed loading associated with anthropogenic sources would correspond to a loading rate of 0.052 $g/m^2/yr$ TP compared to the current load of 0.103 $g/m^2/yr$. Utilizing the phosphorus prediction model, the projected loading rate based on reductions in anthropogenic sources corresponds to an inlake concentration of 0.052 mg/l, over twice the water quality criteria for lakes and reservoirs. It is evident that to achieve the in lake concentration necessary to restore the fishery and meet water quality standards, a greater load reduction must be achieved. Therefore, implementation endpoints might include a combination of feasible management practices including lake treatment for phosphorus removal.

Margin of Safety and Seasonality

A margin of safety (MOS) is a mechanism used to address the uncertainty of a TMDL. The MOS is a required part of the TMDL development process. There are two basic methods for incorporating the MOS (EPA, 1991). One is to implicitly incorporate the MOS using conservative model assumptions to develop allocations. The other is to explicitly specify a portion of the total TMDL as the MOS, allocating the remainder to sources. For the Panguitch Lake TMDL, the MOS was included explicitly by allocating 5 percent of the load capacity to the MOS for the given parameter of concern. Therefore, only 95 percent of the target load was allocated to nonpoint sources. The MOS may be adjusted based on additional sampling of runoff events and further evaluation of the seasonality of loading.

VI. Monitoring Plan

The middle and lower Upper Sevier River segments of the watershed are listed as impaired due to high levels of TDS. The data that were used to list these segments were instantaneous readings for TDS. In the future it will be useful to obtain TDS readings collected over a 24-hour period to better characterize the situation and assess progress towards meeting water quality goals. Furthermore, data for this TMDL were averaged over various periods of time to evaluate seasonal loads and consider the influence of irrigation practices. Additional analysis of the timing of loading events is recommended to further refine management efforts and assess whether water quality targets and endpoints are being met. Future monitoring in a process of evaluation and refinement of TMDL endpoints is recommended.

IX. Public Participation

The public participation process for this TMDL was addressed through a series of public meetings with the Upper Sevier River Watershed Committee. The Watershed Committee is comprised of individuals who represent the interest of stakeholders in the watershed. The committee has participated in this TMDL since the inception of the project, has supported the collection of relevant data and information, and has assisted with the development of management practices. In addition, the committee has developed Project Implementation Plans (PIPs) for implementation of management practices. With respect to the PIPs, the Group will select project participants and give oversight to project planning and implementation, and pursue funding mechanisms to address water quality issues in the watershed. This group actively seeks public input into the prioritization of natural resource problems and concerns. They anticipate volunteer help to be provided at many phases of the project including water conservation, irrigation improvement, tour planning, and media promotion.

A public hearing on the TMDLs was held on --------with notification of the hearing published in the local newspapers. The comment period was opened on ---------- and closed on ------------. In addition, the TMDL and dates for public comment were posted on the Division of Water Quality's website at -------------.

Coordination Plan

Lead Project Sponsor

The Upper Sevier Soil Conservation District (the District) will be the lead project sponsor. The District is empowered by the State of Utah to devise and implement measures for the prevention of nonpoint water pollution. Additionally the District is able to enter into contracts, receive and administer funds from agencies, and contract with other agencies and corporate entities to promote conservation and appropriate development of natural resources. Memoranda of Understanding with state, federal, and local agencies along with individual cooperator agreements empower the District and individual cooperators to accomplish this work.

The Upper Sevier River Watershed Committee (Local Work Group) has brought together citizens who are concerned about the future condition of the Upper Sevier River and its tributaries. They are the primary stakeholders in the future value and future problems that affect this watershed. Utah Association of Conservation Districts is a non-profit corporation that provides staffing for project coordination and financial administration to the Districts of the State of Utah, and specifically to the Upper Sevier Soil Conservation District.

The Upper Sevier River Watershed Committee or an empowered subcommittee, will provide oversight of project conceptualization, cooperator selection, volunteer efforts during implementation, and sharing of information generated by this project with others. The Upper Sevier Soil Conservation District and the Upper Sevier River Watershed Committee will oversee detailed project development, planning, implementation, approval, creation of fact sheets and educational materials, administration and reporting. Some of these duties will be transferred to UACD, NRCS, DEQ, USU Extension Service and others as per Memoranda of Understanding. The Upper Sevier River Watershed Committee will be responsible for writing the final project report pursuant to EPA and State requirements.

UACD will oversee project administration, match documentation, and contracting with agencies and individuals. They will also provide staffing assistance at the direction of the District.

Local Support

The Upper Sevier River Watershed Committee is coordinating with local stakeholders and agencies to develop a watershed plan to further define water quality problems in the Upper Sevier River watershed and to proceed with a coordinated approach to improve water quality within the watershed. The Watershed Committee, working with a Technical Advisory Committee will establish criteria and select cooperators for implementation of projects. This project will be used to show landowners and cooperators Best Management Practices (BMPs) for minimizing land use impacts on water quality in the Upper Sevier River and its tributaries.

Coordination and Linkages

The District and Upper Sevier River Watershed Stewardship Committee anticipate coordinating efforts with the following other entities, agencies, and organizations:

Cooperators - provide match for cost share, implementation of water quality plans
Utah State University Extension - I&E, Technical assistance
NRCS - Technical planning design and oversight
Dixie National Forest- Technical, planning and financial assistance
Utah Department of Agriculture & Food - Technical assistance, I&E assistance
Utah Division of Water Quality - Standard program monitoring, Technical assistance
EPA - Financial assistance
Utah Association of Conservation Districts - Administration, contracting, staff and technical assistance
Utah Division of Water Rights- Permits advisory, and monitoring assistance
Utah Division of Water Resources - Advisory
Upper Sevier County Irrigation Companies - Advisory and TAC coordination

X Implementation Strategy

The following represents a suite of management and restoration options for the improvement of the water quality and fishery of Panguitch Lake. These recommendations are based on analysis which suggests that limited opportunities exist for achieving load reductions from tributaries and nonpoint sources and that internal sediment loading is the dominant source of phosphorus to the lake. However, fishery management alternatives associated with lake treatment for the removal of phosphorus will require extensive review by Division of Wildlife Resource staff to determine the appropriate measures should be taken.

Option 1: **Chemical precipitation of phosphorus**.

Lake restoration through chemical treatment has been demonstrated to be a successful method for the reduction of in-lake P concentrations (Flores and Mosello, 2002; Prepas, et al, 2001; SDPR, 2003; Welch and Cook; 1999). Usually treatment consists of the application of alum (aluminum sulfate) or lime (calcium hydroxide and/or calcium carbonate) which bind with phosphorus in the water column, forming precipitates which settle to the lake bottom. In the case of alum, an aluminum hydroxide floc forms after application which reacts with phosphorus creating an insoluble form aluminum phoshate. Once settled on the bottom this floc can also react with and stabilize sediment phosphorus. Lime application supersaturates the water with Ca^{2+} and precipitates phosphorus as hydroxyapatite. In addition, lime can also induce the flocculation of phytoplankton and the removal of biomass from the euphotic zone. Both resulting precipitates are resistant to re-suspension or release of soluble phosphorus under anaerobic conditions. The effectiveness of these methods depend on a variety of conditions and depend largely on the control of additional sources from tributaries. In a study of eutrophic lakes in Canada, Prepas, et al (2001) found that successive treatments with lime improved water quality for up to 7 years, reducing in-lake phosphorus concentrations between 70 – 91%, Chorophyll a concentrations were reduced 93% after 6 years of treatment. In addition, phosphorus release rates from sediment were reduced 77% during the winter and 37% during the summer. Similarly, alum treatment has been shown to be effective on a number of U.S. lakes controlling, phosphorus for an average of 8 years and reducing internal phosphorus loading by more than 80% (Welch and Cooke,1999).

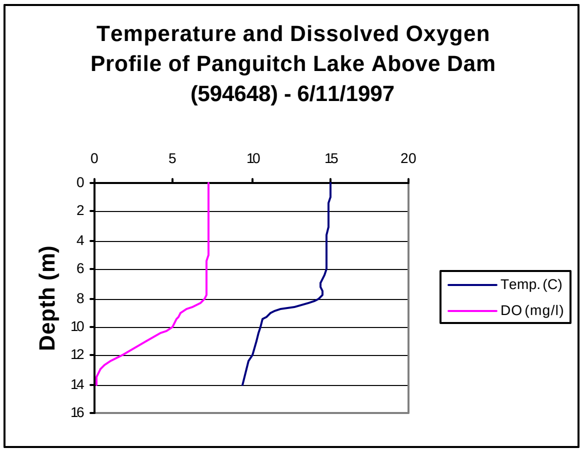
Additional information would be required to determine the appropriate treatment and application rates to treat Panguitch Lake. Typically, chemical treatment is a cost effective method of reducing lake phosphorus and internal loading, particularly compared to the cost-benefit ratio associated with nonpoint source restoration projects. Since the eutrophic loading rate from tributaries is currently very low, the likelihood of achieving the in-lake phosphorus endpoints from watershed restoration and BMPs is low. Therefore, it is recommended that the Division of Wildlife Resources adopt this option as an approach to reducing the internal loading of phosphorus and meeting water quality endpoints in Panguitch Lake.

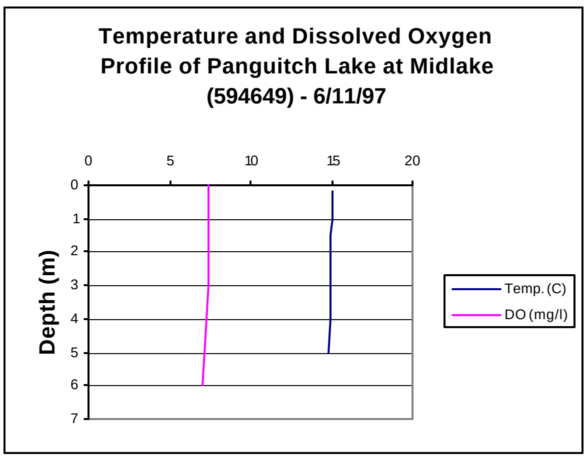
Option 2: BMP Implementation

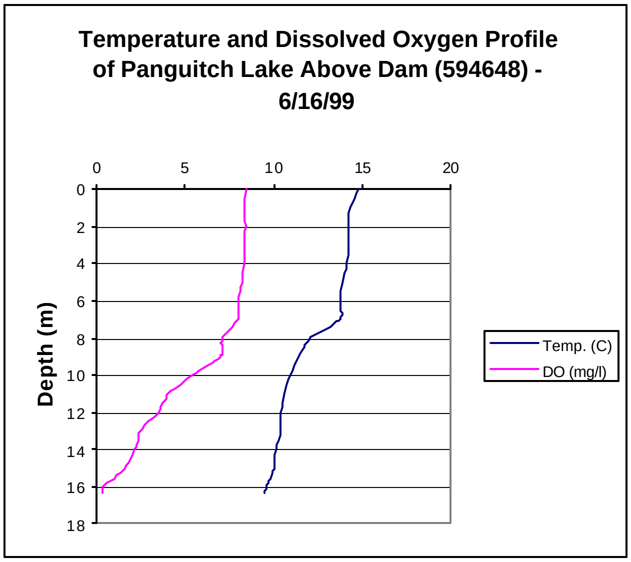
Restoration activities should also be pursued in the Panguitch Lake tributaries to reduce, where feasible, phosphorus and sediment loading to the lake. Chemical treatment of lakes was most successful in cases where external loading was low (Welch and Cooke, 1999). Therefore, reasonable effort should be made to implement the following restoration activities.

1. Since the number of summer homes has increased in the watershed to over 700 developed lots, it is recommended that the Upper Sevier River Steering Committee work with local Health Department officials to assess the impact of on-site systems and identify where systems could be improved or replaced.
2. Streambank restoration efforts should continue particularly in the Blue Spring Creek watershed which contributes the highest load of phosphorus to the lake. Streambank restoration should include grazing management strategies to control the timing and duration of cattle access to limit the degradation of stream habitat from grazing.
3. Limit grazing in lake bed. Grazing below the high water line as lake levels drop during the summer is a major concern for many lakes in the state since animal wastes are readily introduced into the lake when lake levels rise and cover the grazed meadows.

Appendix A. Lake Profiles






Temperature and Dissolved Oxygen Profile of Panguitch Lake Above Dam (594648) - 6/16/99
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15
20
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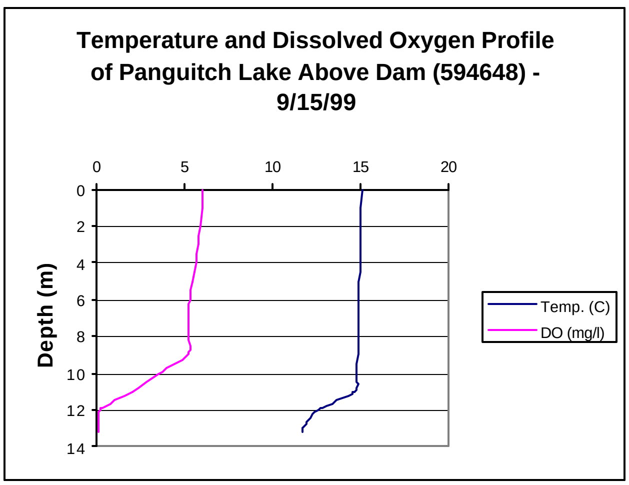
2
4
6
8
10
12
14
16
18
Depth (m)
Temp. (C)
DO (mg/l)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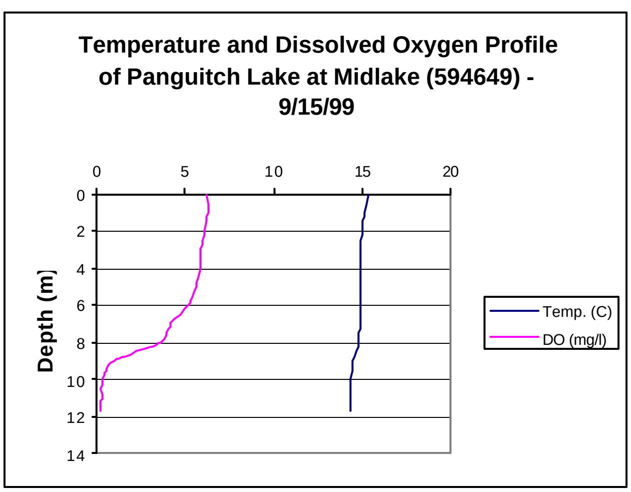
Depth (m)
Temp. (C)
DO (mg/l)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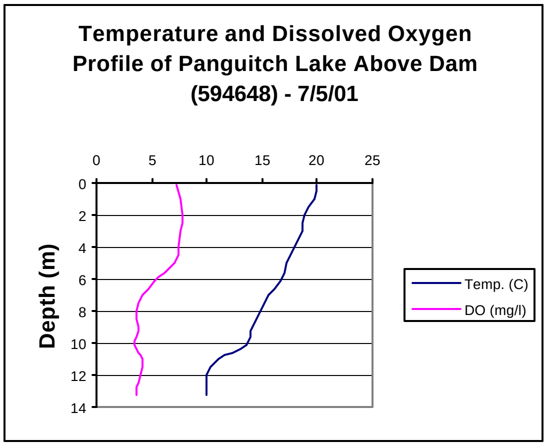
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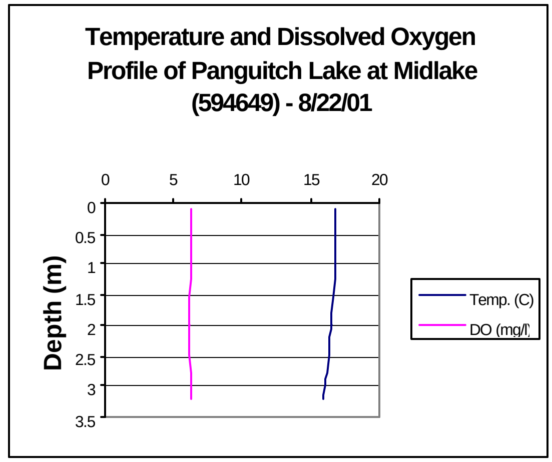
Depth (m)
Temp. (C)
DO (mg/l)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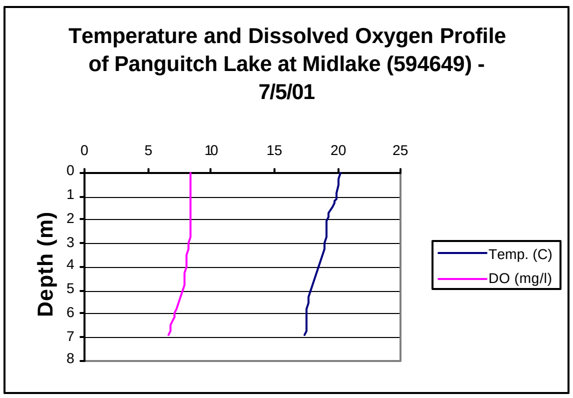
Depth (m)
Temp. (C)
DO (mg/l)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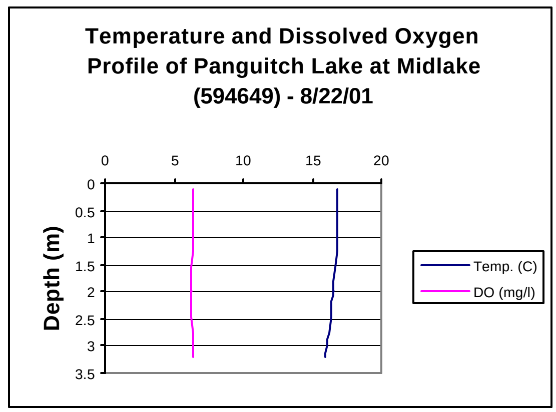
Depth (m)
Temp. (C)
DO (mg/l)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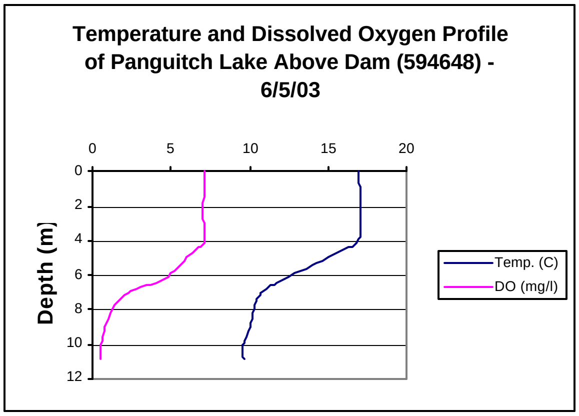
Depth (m)
Temp. (C)
DO (mg/l)


Temperature and Dissolved Oxygen Profile of Panguitch Lake Above Dam (594648) - 6/5/03
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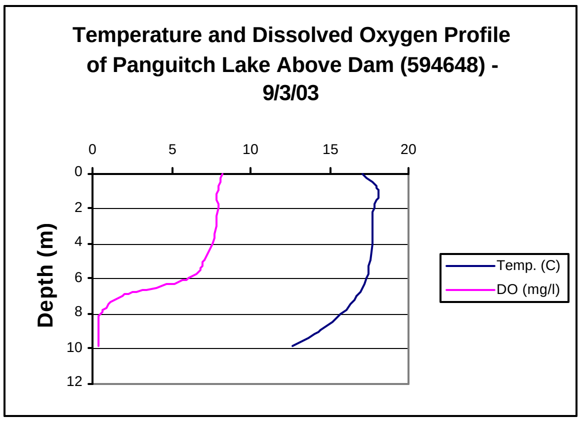
Temp. (C)
DO (mg/l)


Temperature and Dissolved Oxygen Profile of Panguitch Lake Above Dam (594648) - 9/3/03
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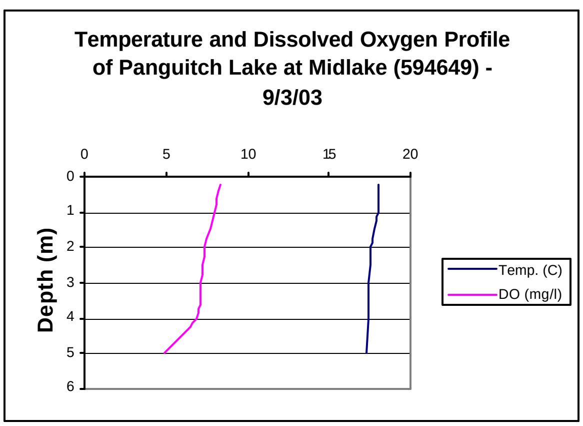
Temp. (C)
DO (mg/l)


Temperature and Dissolved Oxygen Profile of Panguitch Lake at Midlake (594649) - 9/3/03
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Depth (m)
Temp. (C)
DO (mg/l)